Final Report

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Quantifying, Predicting, and Exploiting Uncertainty (QPE)

James F. Lynch
MS #12, Woods Hole Oceanographic Institution, Woods Hole, MA 02543
Phone: (508)289-2230 Fax: (508) 457-2194 e-mail: jlynch@whoi.edu

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http://acoustics.whoi.edu

LONG TERM GOALS

The long term goal of our QPE work is to: 1) quantitatively understand what the uncertainties are in low frequency (10-1500 Hz) acoustic propagation and noise that are caused by variable and complex oceanography and seabed structure, 2) determine the limits to predicting the fluctuating and variable propagation and noise in this frequency regime and others, and 3) ascertain what naval advantage may be gained (if any) by understanding the nature of the uncertainty.

OBJECTIVES

Our (continuing) primary objectives this year were to analyze the data from the main experiment in the East China Sea in 2009, and to work towards explanations of what was observed. Particular emphasis was placed on: 1) ambient noise data analysis, and 2) the theoretical explanation of the azimuthal anisotropy of transmission loss (TL) observed.

APPROACH

The main experiment to the northeast of northern Taiwan was successfully carried out in August-September, 2009. We have methodically looked through the environmental data, the OMAS signal transmission data, and the noise data to identify significant features. The noise data was examined, and bandpass filtered time series were created, as well as a catalogue of interesting events (and their possible origins). Regarding the azimuthal anisotropy of TL, a body of theory was generated which we feel could explain the anisotropy observed in this data set, as well as in the SW06 data set.

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Woods Hole, MA 02543

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Our accomplishments this year included: 1) a catalogue and analysis of the noise, which has been presented as an informal WHOI report, and which shows it to be largely due to intermittent sources, and 2) a body of theory explaining the azimuthal anisotropy seen in TL, both for peak statistics and pulse average statistics. These analyses will be part of two IEEE JOE Special Issue papers which are due to be submitted in Fall 2011.

RESULTS

The noise field seen at the QPE sites was dominated by intermittent sources, and not by wind/waves/distant shipping (i.e. by nearby ships, internal waves, seismic and military sources, fish, earthquakes, explosions, etc). These noises are readily identifiable and classifiable by an operator, and probably automatically (see Figure 1, showing obvious ship noise.) Also, the noise intensities of these various sources can be simply represented by a model with only a few parameters. The intensity of most of these noises can also be predicted on scales of seconds to minutes using a Kalman filter. For both the regular and more "randomly intermittent" noise signals, one can form a pdf of each source's behavior, and then use this in Dyer's Predictive Probability of Detection (PPD) formalism (which is a good descriptor of Uncertainty in sonar equation). This is a "through the sensor" approach to building a locally useful PPD, and also predicting noise over the short term. To do this, some technical work is needed in pattern recognition, classifier training, modeling, forming statistics, and Kalman filtering, but all of these are rather standard

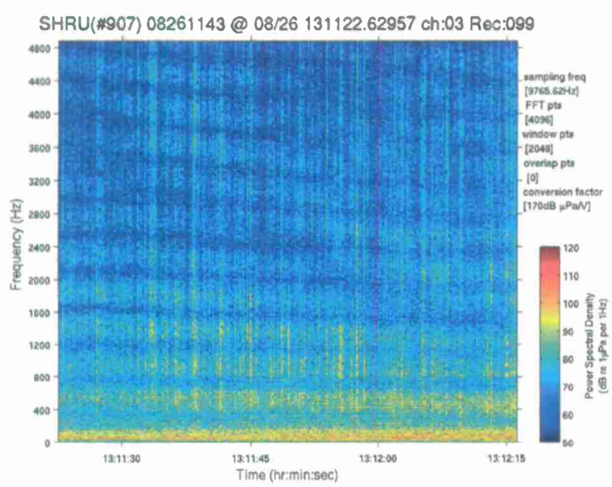


Figure 1. Typical nearby ship noise signature seen in the QPE SHRU data, one of the many dominant "transient" noise sources.

Regarding the azimuthal dependence of the transmission loss (TL) in QPE, we have good circular track data for both peak TL (the matched field peak) and for the integrated TL (integrated over an arrival sequence length). Peak TL is a good metric for detection, whereas integrated TL is a good metric for energy detector line tracking – both have their uses. An example of a peak TL measurement in QPE is shown in Figure 2 (top panel), and for integrated TL in Figure 2 (bottom panel).

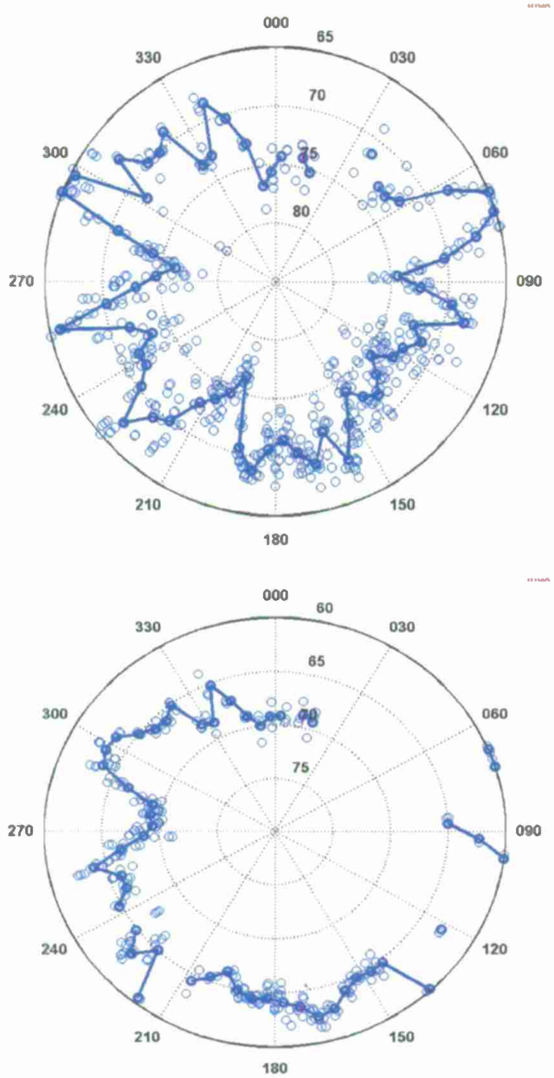


Figure 2. Top panel shows peak TL obtained from a circular track in the QPE experiment using five degree bins. Bottom panel shows integrated TL for same raw data, also using five degree binning.

From work in SW06 (Lynch et al AWACS paper, accepted for JASA), we think we now understand how the azimuthal TL variability is explained physically. The angular regimes proposed by Badiey and Katznelson have been found useful in this explanation. For instance, peak TL has a peak width distribution of sizes from small to large. This reflects that the focusing, refraction, adiabatic and coupled angular regimes all contribute. (Peak TL involves coherent, phase addition effects). However, the integrated TL peak width distribution has only small and large peak widths. Only out of plane diversion of energy (in the focusing regime, with small peak widths) and coupling induced losses/gains (in the coupling regime, with large peak widths) result in a change of the total energy. Regarding Uncertainty, we note that if we had a deterministic, simple ocean (surface, volume, bottom), we could predict the TL angular pattern. However, for real ocean structure and variability, we should look at the pdf of TL (f,R,θ,BL). This is the quantity we should input to Dyer's PPD for Uncertainty.

IMPACT/APPLICATIONS

The impacts of our work so far are that we have seen interesting effects concerning: 1) azimuthal anisotropy, 2) ambient noise, and 3) propagation over slopes and canyons that may have naval sonar implications. We also are tying in to the larger Prediction, Quantification, and Exploitation of Uncertainty theme via the Dyer PPD.

TRANSITIONS

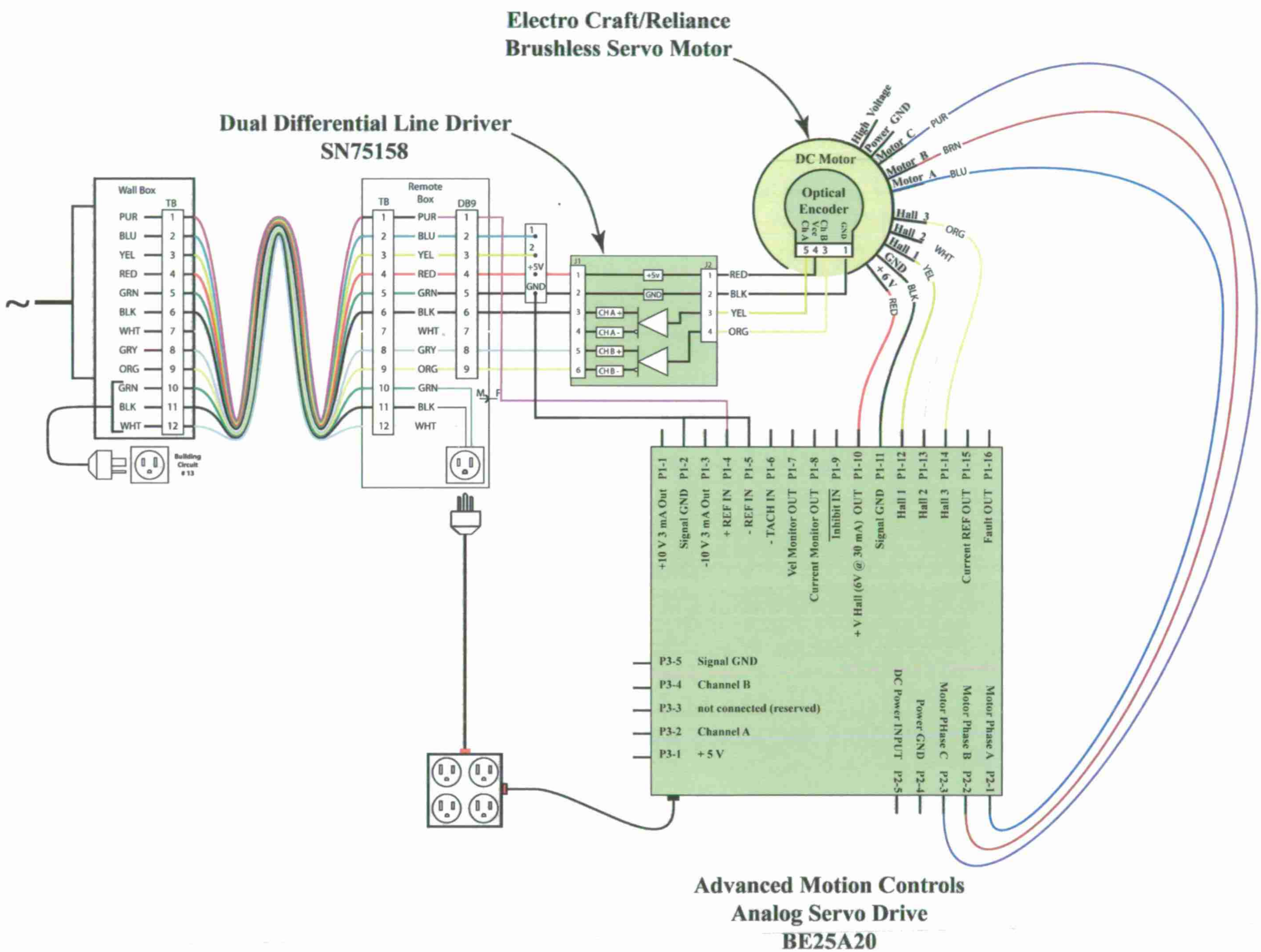
One eventual transition of our work will be to naval sonar systems and to sonar analysis, where the interest is in "the error bars" in ocean acoustic field and system performance prediction.

RELATED PROJECTS

The SW06 experiment also had an Uncertainty-related component, only in a different geographical area. A cross comparison of the azimuthal TL results between the two sites is in progress.

PUBLICATIONS (non-refereed)

Shemelev, A. and J.F. Lynch. "A theoretical and computational look at the physics of acoustic propagation through crossing ocean waves." Proceedings of the ICTCA. (2011)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